Prediction of surface roughness through the roughness parameter Rz, during hard turning of steel C 55 (DIN) using mixed ceramics MC 2 (Al2O3 + Ti C)

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Abstract— Surface roughness parameters are normally categorized into three groups according to its functionality, which are defined as amplitude parameters, spacing parameters, and hybrid parameters. In this course, an attempt has been made to explore the effect of process parameters speed, feed, and depth of cut as well as geometric property or radius of the cutting insert on Surface Roughness characteristic Rz in hard turning of steel C 55 (DIN) using mixed ceramics MC 2 (Al2O3 + Ti C). Rz is roughness parameter that is usually called ten point average heights or the average maximum peak to valley of five consecutive sampling lengths within the measuring length. Significant number researchers consider roughness parameter Rz more relevant in comparison with the roughness parameter Ra which is one of the most used roughness parameter of the surface roughness topography characterization. This is due to the fact that Rz describes in more accurate manner the depth of the valleys, which is very significant property in terms of the exploitation when it comes to the surfaces that need constant and consistent lubrication as the action to minimize friction and allow smooth movement of interacting components.

Index Terms— Ceramics, Feed, Parameters, Profile, Radius, Roughness, Speed, Hard Turning

1 Introduction

In order to achieve the desired surface quality, various technological processes have traditionally been used, which are constantly perfected in order to adapt to the requirements set by the technical standards, ensuring their high exploiting reliability. By technical standard are meant: the dimensional accuracy and the appropriate characteristics of the finished surface layer, while with exploitative quality: resistance to corrosion, tool consumption, resistance to loads, etc. In other word, the challenge of modern machining is to achieve high quality, in terms of dimensional accuracy, surface finish and high production rate.

Hard turning is considered as a new machining process aimed at turning hardened steels with high surface qualities, this process is good alternative for many grinding applications which were previously done through traditional machining processes [1].

At the end of the last century, The forecast of the International Committee for Mechanical Technology (CIRP) confirmed the dominant role of the hard turning process in the entire production process as of year 2000 [2]. The turning process represents a set of related phenomena that are in close interaction. They condition the course of the decohesion process, in which the state of cutting tool wear plays a significant role [3].

Turning process is one of the main technological processes for obtaining machine parts from semi-finished products. We group this technological process based on the way it works, the machines used, cutting tools, etc. [4].

About the advantages and benefits that this process offers, there is a lot of data which derives mainly from experimental research, where, in the first place, the questions related to the mechanics of the turning process and the factors that determine its flow and technological consequences that are imposed. Among those issues (questions), the cutting tool takes an important place, its quality, cutting ability, durability and reliability, the quality of the product and the overall economic dimension. It can be concluded that among modern cutting materials, ceramic cutting inserts play a serious role, thanks to their numerous advantages and relatively moderate cost.

The physical and mechanical properties of cutting ceramics (especially their sensitivity to thermal shocks) require research in this direction. Moskalski in his work "Ceramic as a prospective tool material for processing." emphasizes the high sensitivity of ceramic cutting inserts with oxide base of changeable forces and heat loads, based on experimental tests with interrupted turning [5].

Hoszowski ib his PhD thesis "Identification of wear of ceramic insert blades on the example of high-speed turning of KH15AG bearing steel" noted that the application of Al_2O_3 oxide base to the ceramic cutting board components of ZrO_2, TiC, creates an increasing number of micro-cracks with the increase with the number of periodic thermal and force shocks. [6]

Kundrak et al in his research work ", Accuracy of hard turning" claims that hard turning owes its pop-

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ularity primarily to the capability of generating complex geometric surfaces with better form accuracy and improved tolerances in one single pass [7]

From the above, we can conclude that achieving the desired quality requires the design of such processes which imply high harmonization of the interaction of the parameters which make up the technological system of machining, respectively explored input parameters(workpiece, cutting parameters, geometric parameters), researched process parameters (physic-chemical cutting mechanism (tribological phenomena, thermal phenomena, dynamic phenomena) and explored output parameters (technological effects such as accuracy, surface layer quality, durability and resistance of cutting tools, economic effects, etc.).

According to numerous authors, the higher the number of parameters used, a more accurate description can be obtained. This is one of the reasons for introducing new parameters of surface evaluation.

Surface roughness parameters are normally categorized into three groups according to its functionality, which are defined as amplitude parameters, spacing parameters, and hybrid parameters. In this course, an attempt has been made to explore the effect of process parameters speed, feed, and depth of cut as well as geometric property or radius of the cutting insert on Surface Roughness characteristic Rz in hard turning of steel C 55 (DIN) using mixed ceramics MC 2 ($Al2O3$ + Ti C). Rz is roughness parameter that is usually called ten point average heights or the average maximum peak to valley of five consecutive sampling lengths within the measuring length. Significant number researchers consider roughness parameter Rz more relevant in comparison with the roughness parameter Ra which is one of the most used roughness parameter of the surface roughness topography characterization. This is due to the fact that Rz describes in more accurate manner the depth of the valleys, which is very significant property in terms of the exploitation when it comes to the surfaces that need constant and consistent lubrication as the action to minimize friction and allow smooth movement of interacting components.

Surface roughness evaluation is very important for many industrial problems such as friction, contact deformation, heat and electric current conduction, tightness of contact joints and positional accuracy. For this reason surface roughness has been the subject of experimental and theoretical investigations for many decades. The real surface geometry is so complicated that a finite number of parameters cannot provide a full description [8].

Rech et al studies the process of surface finishing of bearing steel AZSE 52100 by using ceramic and PCBN tools. Hard turning by both tools produced surface with roughness Rz=1-2 μm and Ra=0.1 - 1μm.

Wanat et al studied the roughness of surface produced through hard turning of low-chrome allyed steel by ceramic tools having wiper or normal geometries. Results indicated the normal geometry created a roughness of Rz=1.55 μm and Ra=0.28 μm with a feed rate of 0.04 mm/rev, while wiper geometry tools created a roughness of Ra=1.62 μm with a federate of 0.1 mm/rev [9].

2. Experimental Procedure

Work piece, Material and Tool - Hard turning is performed on rings, specially made for this purpose, from material improved steel C 55 (DIN). The rings have been additionally heat-treated to the required hardness of 52 ± 2 HRC. Dimensions of the rings are φ 102 x Φ 82 x 20 mm, figure 1. The rings are mounted on a device specifically designed for this purpose, to investigate the roughness of the surface layer in order to increase the stiffness of the rings, figure 2.

Figure 1. Rings of material C 55 (DIN), with hardness 52 ± 2 HRC

The rings have previously been subjected to heat treatment by annealing, in order to remove the residual stresses remained from the previous treatments and achieve approximately equal structural condition in all rings before the start of the experiment.

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Figure 2. Special set up for exploring the characteristics of the surface layer during turning.

Research equipment

Figure 3. a) The CSRNR 25x25 M12H3 cutting board holder from HERTEL, b) Cut-off inserts SNGN 120708-120712-120716 from mixed ceramics MC 2 (Al_2O_3 + TiC) from the company HERTEL

Hard turning is performed using SNGN 120708-120712-120716 from mixed ceramics MC 2 (Al_2O_3 + Ti C), made by HERTEL, Figure 4. with the cutting tool stereometry: κ=750; κ 1=150; γ = -60; α = 60; λ = - 60; r = 0.8-1.2-1.6 mm; γf = 200; bf = 0.2 mm.
A conventional lathe model TVP 250 from the company Prvomajska, Figure 6, with a spindle power P = 11.2 (Kw), with the following speed revolutions 16 - 2240 (rot. /min.), and feed rate 0.025-1.12 (mm/rev), was utilized

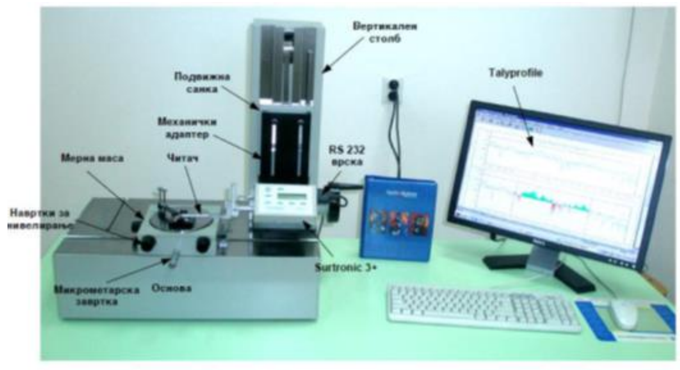

Figure 4. Computerized measuring device model Surtronic 3+ from Taylor Hobson and Talyprofile software for measurements of the profiles

3. Analysis of research results

The machining is performed by changing four independently variable parameters: cutting speed (*v*), cutting feed rate (*f*), cutting depth (*a*) and the cutting insert radius (*r*), using a four-factorial experiment ($2_4 + 4$).
The change in independently variable sizes is shown in table 1. The designed planning and the experimental results obtained are presented in Tables 2-4. After computing and collecting data by the appropriate software, the variations in parameter size can be represented by mathematical model (2).

TABLE 1. CHARACTERISTICS OF INDEPENDENT VARIABLES

Parameters		Level		
	Code	High	Medium	Low
		1	0	-1
1 v (m/min.)	X 1	133.00	94.00	67.00
2. f (mm/rot.)	X 2	0.315	0.177	0.13.
3. a (mm)	X 3	0.8	0.56	0.4
4. r (mm)	X 4	1.6	1.13	0.8

Four-factorial plan of first-order experiments is performed by real plan matrix and coded plan matrix;
Correlation of the input-output information for a mathematical model of the first order with/without interaction and with/without significance assessment of the factors (b1);
In the same manner variation of interactions of input parameters and assessments of the significance were performed, where established confidence interval level of 95%.

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Investigation of the parameter Rz.

TABLE 2. FOUR-FACTORIAL PLAN OF FIRST-ORDER EXPERIMENT

Four-factorial plan of first-order experiments					
Nr.	Real plan matrix - independent variables				Measured values
	v (m/min.)	f (mm/vr.)	a (mm)	r_ε (mm)	Rz (um)
1.	67.00	0.1	0.4	0.8	2.930
2.	133.00	0.1	0.4	0.8	2.970
3.	67.00	0.315	0.4	0.8	15.067
4.	133.00	0.315	0.4	0.8	14.333
5.	67.00	0.1	0.8	0.8	3.623
6.	133.00	0.1	0.8	0.8	2.753
7.	67.00	0.315	0.8	0.8	15.500
8.	133.00	0.315	0.8	0.8	14.400
9.	67.00	0.1	0.4	1.6	2.073
10.	133.00	0.1	0.4	1.6	1.443
11.	67.00	0.315	0.4	1.6	7.093
12.	133.00	0.315	0.4	1.6	6.393
13.	67.00	0.1	0.8	1.6	1.767
14.	133.00	0.1	0.8	1.6	1.870
15.	67.00	0.315	0.8	1.6	7.720
16.	133.00	0.315	0.8	1.6	8.360
17.	94.00	0.177 (0.18)	0.566	1.13 (1.2)	5.290
18.	94.00	0.177 (0.18)	0.566	1.13 (1.2)	5.590
19.	94.00	0.177 (0.18)	0.566	1.13 (1.2)	5.280
20.	94.00	0.177 (0.18)	0.566	1.13 (1.2)	4.587

TABLE 3. ASSESSMENT OF THE IMPORTANCE OF THE MODEL (IN THIS CASE WITHOUT ASSESSMENT AND WITHOUT IMPORTANCE OF THE PROCESS VARIABLES)

Mathematical model of the first order without interaction							
Coefficients of the mathematical model			Degree of freedom F(i)	Sum of squares S(i)	Dispersion S(i)/F(i)	Dispersion relation FR(i)	Evaluation of the significance of factors b (i)
Index (i)	Coded (i)	Decoded p(i)					
0	1.605	102.895	1	51.499	51.499	7224.8	significant
1	-0.04466	-0.1302555	1	0.031905	0.031905	4.5	insignificant
2	0.75064	1.308	1	9.015	9.015	1264.8	significant
3	0.03887	0.1121491	1	0.024171	0.024171	3.4	insignificant
4	-0.31089	-0.8970264	1	1.546	1.546	216.9	significan
If FR(i) < 10.130 = > insignificant				If FR(i) >= 10.130 = > significant			

For more detailed analysis, mathematical models with/without interaction and with/without significance assessment of the factors have been adopted; where all varied independently variables included. This enables us to explain the effects of input parameters *v, f, a* and *r* on subsequent changes, these models are characterized by a high coefficient of multiple regression 95%. Performed analysis, after completed and computed, showed adequacy of obtained mathematical model.

$$\mathbf{Rz = 102.895\ v^{-0.1302555}\ f^{1.308}\ a^{0.1121491}\ r^{-0.8970264}}$$

The graphical interpretation of the mathematical table 1, 2, 3, is presented in fig. 5 – 10 . using MAtlab.

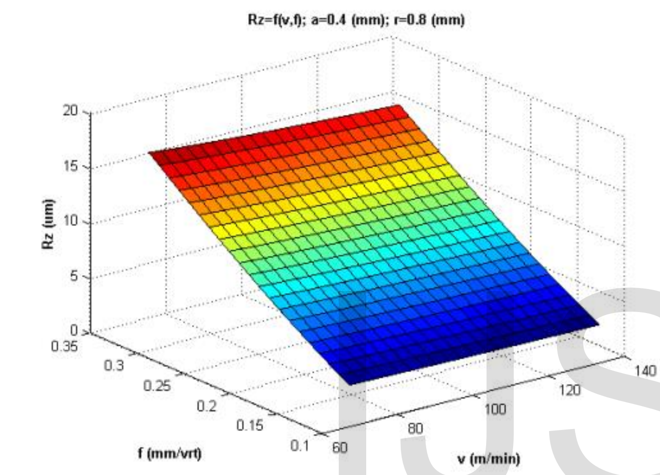

Figure 5. Graphic representation of the roughness parameter Rz (◎m) as a function of the cutting speed v (m / min) and the displacement f (mm / rot), at a = 0, 4 (mm) and r_ε = 0, 8 (mm).

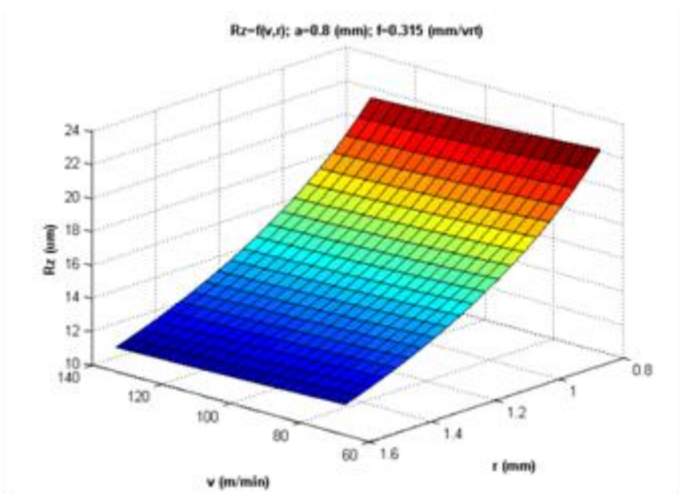

Figure 6. Graphic representation of the roughness parameter Rz (◎m) as a function of the cutting speed v (m/min) and the radius at the top of the

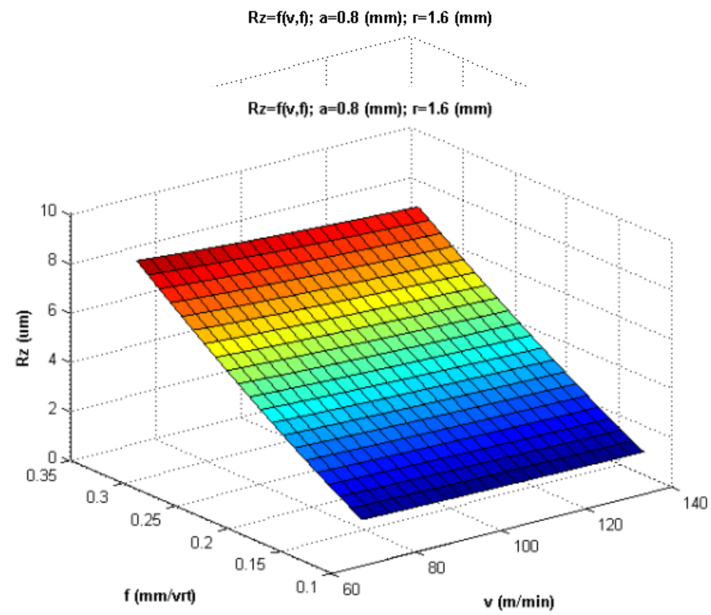

Figure 7. Graphic representation of the roughness parameter Rz (◎m) as a function of cutting speed v (m / min) and displacement f (mm / rot), at a = 0,8 (mm) and r_ε = 1,6 (mm).

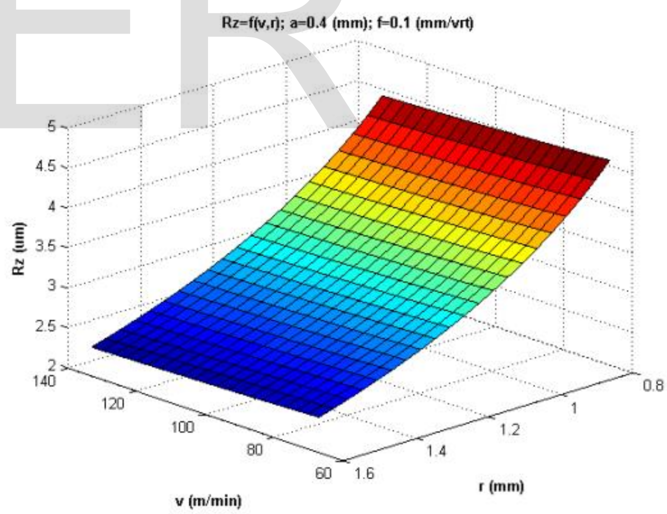

Figure 8. Graphic representation of the roughness parameter Rz (◎m) as a function of the cutting speed v (m/min) and the radius at the top of the cutting board r_ε (mm), at a = 0,4 (mm) and f = 0.1 (mm/rot).

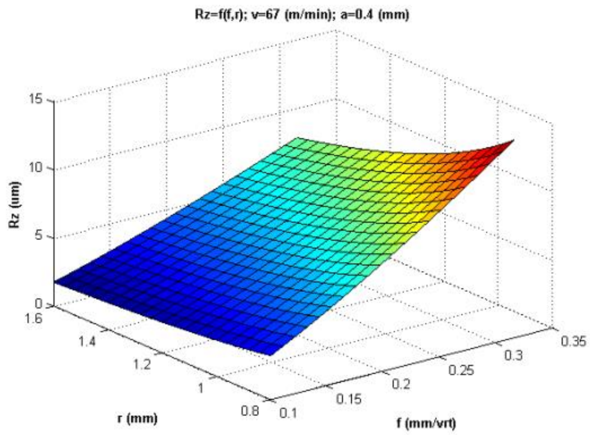

Figure 9. Graphic representation of the roughness parameter Rz (◎m) as a function of the displacement f (mm/rot) and the radius at the top of the cutting board r_ε (mm), at v = 67 (m / min) and a = 0, 4 (mm).

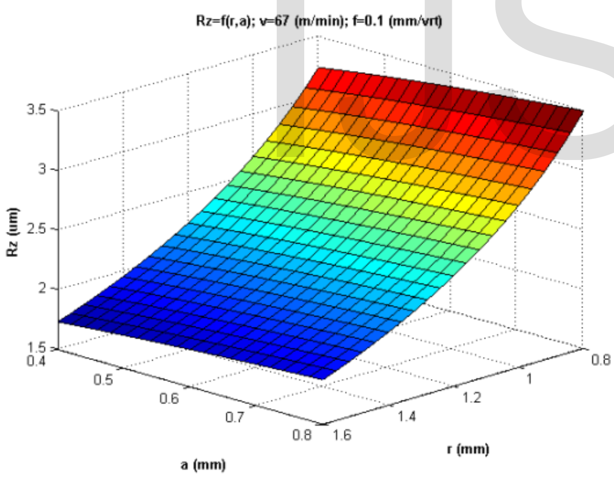

Figure 10. Graphic representation of the roughness parameter Rz (◎m) as a function of the radius at the top of the cutting board r_ε (mm) and the cutting depth a (mm), at v = 67 (m / min) and f = 0, 1 (mm /rot).

Recommendations

Inclusion of the roughness parameters R_z , in this paper, that are directly measurable and related to the exact values of the peak to valley depth, should represent useful contribution to the direction of conventional description of the roughness profile , due to the fact that the above mentioned, gives the scientific justification of the proposed topic.

The empirical results obtained from this research are expected to have practical applicability. Their application in the metal processing industry can create conditions for process optimization and gaining economic benefits from.

Conclussion

From the experimental procedures and data processing, we can observe the difference between the amplitude roughness parameters Ra and Rz! While observing the geometric shape of the roughness parameter Rz we clearly notice the height difference between the peaks and the valleys, whilst in center line average or roughness parameter Ra we are not considering this difference or peak to valley height, because it is actually an average of the departure of the whole profile from the mean line, in other words, it doesn’t provide us with the real quantified value about the depth of asperities. So, from the above we can get an idea about the advantage of the surface roughness parameter Rz, that means get the quantification of the depth of valleys. Finally we can conclude that from the engineering perspective that roughness parameter Rz is Rz more relevant in comparison with the roughness parameter Ra which is one of the most used roughness parameter of the surface roughness topography characterization. This is due to the fact that Rz describes in more accurate manner the depth of the valleys, which is very significant property in terms of the exploitation when it comes to the surfaces that need constant and consistent lubrication as the action to minimize friction and allow smooth movement of interacting components.

REFERENCES

[1] [E.D.Derakhshan, A.A. Akbari, 2009, Experimental Investigation on the effect of workpiece hardness and cutting speed on surface roughness in hard turning with CBN tools, Proceedings of the World congress on Engineering 2009 Vol II, WCE 2009, July 1-3, London, U.K.]

[2] [Zebrowski H.: Teoretycznie i doswiadczalne podstawy obróbki skrawaniem. Prace Instytutu Technologii Budowy Maszyn Politechniki Wroclawskiej. Podstawy technologii Maszyn, 1990.]

[3] [Kuzinovski M, Research on the physical phenomena and technological effects during hard turning with high speed - Doctoral dissertation, page (3)

[4] 1964Arshinov V.A., Aleksiev G.A. Metal cutting and cutting tools. Mechanical Engineering Publishing House Moscow 1964.]orignal: [Аршинов В. А., Алексеев Г. А. Резание металлов и режущий инструмент. Издательство машиностроение *Москва*

[5] Hoszowski, T.,Vogel, Z. “Spieki ceramiczne jako perspektywiczny material marzedziowy do obrobki viiorewej. V OGOLNOPOLSKA KONFERENCIJA NAUKOWO-TECHNICZNA. ZIELONA GORA – WRZESIEN 1987; S.116 – 120.] (117)

[6] [Moskalski, K., Identyfikacija zuzhucia ostrzy ceramicznych na przykladzie toczenia szybkosciowego stali lozyskovej KH15AG. Praca doktorska. Poznan, 1983.]

[7] [Kundrak, J.,B.Karpuschewski, K.Gyani, & V.Bana, Accuracy of hard turning. Jurnal of Materilas Processing Technology, 2008. 202(1-3):p.3280338.]

[8] E.S. Gadelmawla, M.M.Koura, T.M.A.Maksoud, I.M.Elewa, H.H.Soliman, 2002, Roughness Parametrs, Production Engineering and Mechanical Design Department, Mansoura University, Mansoura, Egypt.

[9] [W. Grzesik, J.Rech, T.Wanat."Surface finish on hadened bearing steel parts produced by superhard and abrasive tools". International Journal if Machine Tools & Manufacture 47 (2007) 255-262.]